REMARKS

Status of the claims:

Claims 1, 3-5, 7, 9-11, 13-14, and 16-25 are pending and ready for further action on the merits. Reconsideration is respectfully requested in light of the following remarks.

Rejections under 35 U.S.C. § 103

Claims 1, 3-5, 7, 9, 11, 13-14, 16-20 and 22-25 are rejected under 35 U.S.C. 103(a) as being unpatentable over Rivin '304 (US Patent No. 5,322,304).

Claims 10 and 21 are rejected under 35 U.S.C. 103(a) as being unpatentable over Rivin '304 in view of Slocum '126 (US Patent No. 6,280,126),

Applicants traverse.

Applicants assert that the Examiner has failed to establish a proper *prima facie* case of obviousness for either of the above-enumerated rejections. To establish a proper *prima facie* case of obviousness, three basic criteria must be met.

1) There must be some suggestion or motivation, either in the references themselves or in the knowledge generally available to one of ordinary skill in the art, to modify the reference or to combine reference teachings.

2) There must be a reasonable expectation of success.

3) The prior art reference (or references when combined) must teach or suggest all the claim limitations.

See *In re Vaeck*, 947 F.2d 488, 20 USPQ2d 1438 (Fed. Cir. 1991) and MPEP 2142.

Applicants submit that the Examiner has failed to show any of these criteria. For example, however, the Examiner has failed to show criteria 1) that there must be some

suggestion or motivation, either in the references themselves or in the knowledge generally available to one of ordinary skill in the art, to modify the reference or to combine reference teachings.

In this regard, Applicants direct the Examiner's attention to *In re Gordon*, 733 F.2d 900, 221 USPQ 1125 (Fed. Cir. 1984) that holds that if a proposed modification would render the prior art invention being modified unsatisfactory for its intended purpose, then there is no suggestion or motivation to make the proposed modification (also, see MPEP 2143.01 V.).

Applicants respectfully submit that the purpose of Rivin '304 is to create a better fit for a conical envelope in a conical seat. At column 2, lines 3-8, Rivin '304 states:

> *According to the invention, the conical envelope is resilient so as to allow simultaneous seating of the conical envelope in the conical seat and seating of the clamping surface on the clamping seat irrespective of the tolerances between the conical seat and the clamping seat.*

This passage describes that Rivin '304 is attempting to allow for better seating of the conical envelope in the conical seat (*i.e.*, a better fit). Moreover, in this passage it is apparent that Rivin '304 does not care about tolerances (such as damping). The intended purpose of Rivin '304 is to achieve a better fit irrespective of the tolerances such as damping. Accordingly, if one were to allow machined depressions in Rivin '304 as the Examiner asserts is obvious, then the purpose of a good fit of the conical envelope in the conical seat in Rivin '304 would be destroyed. If the purpose of Rivin '304 is destroyed, as a matter of law, Rivin '304 cannot render *prima facie* obvious the present invention (see the holding of *In re Gordon*).

Moreover, the inventors of the present invention, who are experts in the field, herewith submit 37 CFR 1.132 declarations declaring that their understanding of the

purpose of the Rivin '304 reference is to attain a better fit for a conical envelope in a conical seat. Applicants also herein submit as Appendix 1, a peer reviewed reference (Smith et al., Annals of the CIRP, Vol. 48(1), pp. 293-296, (1999)) that shows that the increased force between one surface and another surface (leading to a better fit) causes a decrease in damping effects.

Thus, even if *arguendo*, Rivin '304 were available to make the present invention *prima facie* obvious, which Applicants do not concede, the present invention has unexpectedly superior properties that renders it patentable over either or both of Rivin '304 and/or Slocum '126. For example, the present invention has damping properties that are neither contemplated nor taught by either of Rivin '304 or Slocum '126. By having depressions that are machined (as claimed), the present invention has increased damping properties (*i.e.*, the damping properties are better) but may have a worse fit. As was discussed above, the purpose of Rivin '304 is to create a better fit for a conical envelope in a conical seat. When a better fit is created, the damping properties decrease (*i.e.*, there is less damping). Please note the Smith et al. reference submitted with this response shows that an increased force between one surface and another surface (leading to a better fit) causes a decrease in damping effects. Thus, Rivin '304 has poor damping tolerances. Slocum '126 fails to make up for this deficiency in Rivin '304. Accordingly, neither of Rivin '304 or Slocum '126 individually or together can render obvious the present invention.

Applicants further submit that when Rivin '304 is read as a whole, it teaches away from the present invention. The Rivin '304 reference has as its intent a better fit for a conical envelope in a conical seat. As was described in detail above, and when read in

conjunction with the Smith et al. reference submitted herewith, it should be apparent to those of ordinary skill in the art that a better fit results in decreased damping, an intent that is diametrically opposite to one of the intended purposes of the present invention. For the reasons described above, the rejections are inapposite. In other words, Rivin '304 and/or Slocum '126 cannot render obvious the present invention. Withdrawal of the rejections are warranted and respectfully requested.

CONCLUSION

With the above amendments and remarks, Applicants believe that all objections and/or rejections have been obviated. Thus, each of the claims remaining in the application is in condition for immediate allowance. A passage of the instant invention to allowance is earnestly solicited.

Applicants believe that no additional fee is necessary, however, should a fee be deemed to be necessary, the Commissioner is hereby authorized to charge any fees required by this action or any future action to Deposit Account No. 16-1435.

Should the Examiner have any questions relating to the instant application, the Examiner is invited to telephone the undersigned at (336) 607-7486 to discuss any issues.

Respectfully submitted,

Date: September 15, 2006

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APPENDIX 1

The Effect of Drawbar Force on Metal Removal Rate in Milling

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Abstract

The metal removal rate in milling is often limited by the tool-spindle dynamics. Higher stiffness and damping as seen at the tool tip allow higher metal removal rates. While increasing the drawbar force leads to greater static stiffness in the tool-spindle interface, dynamic measurements indicate that higher drawbar forces also diminish the damping. Whether higher drawbar force is beneficial for stable metal removal depends on whether the gain in stiffness is greater than the loss in damping. This paper presents test-stand measurements of stiffness and damping for tool holder - spindle interfaces at various drawbar forces, and similar measurements in spindles.

Keywords: Milling, Metal removal rate, Dynamic stiffness

1 INTRODUCTION

It is well-known that the metal removal rate which can be achieved in a milling operation depends very strongly on the dynamic characteristics of the machine - tool - workpiece system, as seen in the interface between the tool and the workpiece. In particular, the dynamic stiffness as characterized by the Frequency Response Function (FRF) sets limits on machining performance [1]. In most instances the dynamic characteristics of the tool, toolholder, and spindle dominate.

The dynamic characteristics as seen at the tip of the tool are affected strongly by the characteristics of the connection between the tool and the spindle. Considerable effort has been devoted recently to the computation and measurement of the static stiffness, accuracy, repeatability, torque capacity, and limiting speeds of various toolholder - spindle interfaces [2], [3], [4], [5].

While all of these reported measurements are of high quality, measurement of the damping is also required for an evaluation of the machining performance. Our paper presents some results which substantially reproduce the static stiffness measurements, but which include the damping effects as well.

2 TEST-STAND MEASUREMENTS

At the University of North Carolina at Charlotte, we used a very rigid test stand to evaluate the stiffness of the toolholder - spindle interface. The test stand could be fitted with a variety of spindle interface noses, and was equipped with an instrumented drawbar which was used to measure the drawbar force.

Static stiffness measurements were made by applying a load at the tip of a simulated tool using a hydraulic cylinder and a load cell. Static deflections were measured using capacitance probes. Figure 1 shows a typical result for a HSK 100A connection for drawbar forces between 25 and 55 kN. This measurement indicates that as the drawbar force is increased, the static stiffness also increases. However, the differences in the stiffness are not great for bending moments up to about 500 Nm. Our results in this area substantially confirm the results presented in Reference [3].

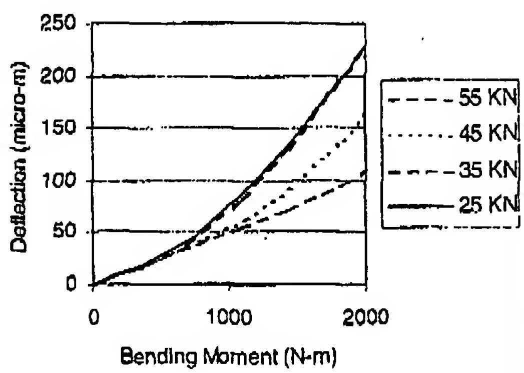

Figure 1: Static deflection versus bending moment for an HSK 100 A connection.

Additionally, we used impact excitation to measure the dynamic characteristics in the form of the FRF. Figures 2 and 3 show a typical result. This is a measurement of the Real part (Figure 2) and the Imaginary part (Figure 3) of the FRF for a CAT 50 connection at a drawbar force of 12 kN. In these figures, it can be seen that there is one dominant mode.

Mode shape measurements indicate that this mode strongly involves the toolholder - spindle connection. The modal stiffness and damping can be extracted from this measurement.

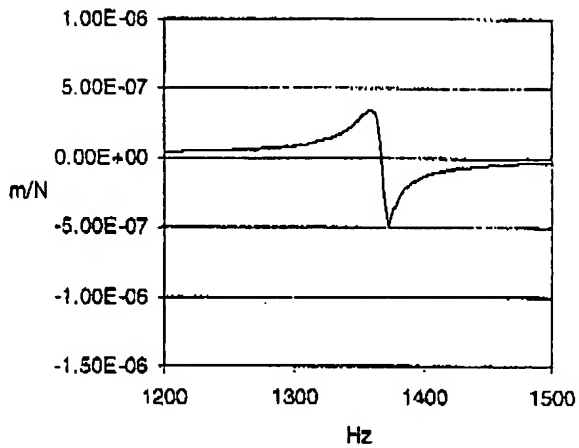

Figure 2: Real Part of a Frequency Response Function for a CAT-50 holder with a 12 kN drawbar force.

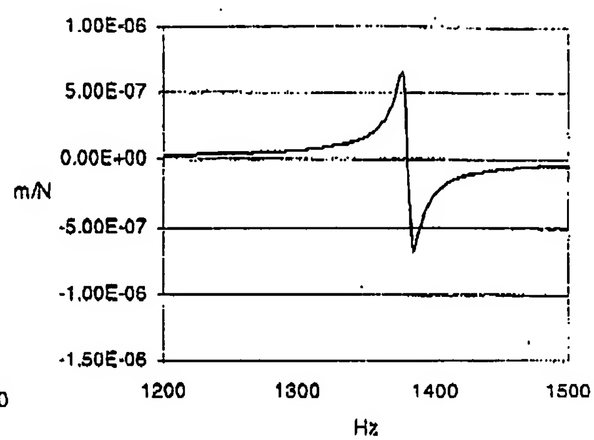

Figure 4: Real Part of a Frequency Response Function for a CAT-50 holder with a 32 kN drawbar force.

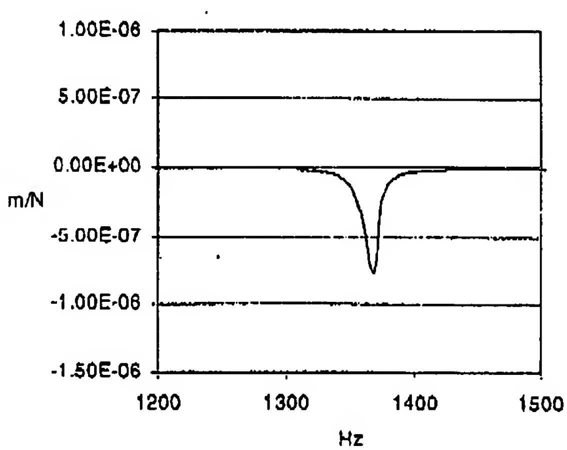

Figure 3: Imaginary Part of a Frequency Response Function for a CAT-50 holder with a 12 kN drawbar force.

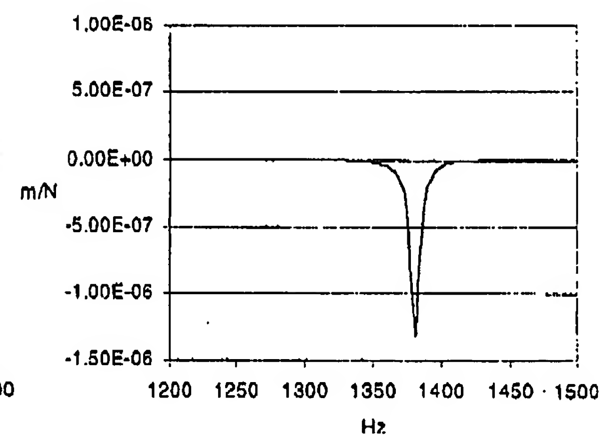

Figure 5: Imaginary Part of a Frequency Response Function for a CAT-50 holder with a 32 kN drawbar force.

Figures 4 and 5 show a measurement corresponding to the same set-up as Figures 2 and 3, but with a higher drawbar force (32 kN). It can be seen that the peak of the Imaginary Part is about 50% larger for the higher drawbar force, indicating that the product of stiffness and damping is smaller. The static measurements show that the stiffness has increased, but the dynamic measurements show that the damping has decreased, with the change in damping outweighing the change in stiffness.

Figure 6 shows the product of the stiffness and damping plotted versus drawbar force for several different holders (different classes of fit). In all of these cases, the trend for the product of stiffness and damping is lower as the drawbar force is increased.

3 MEASUREMENTS IN MILLING SPINDLES

Of course, the test stand measurements were intended to measure the characteristics of the toolholder - spindle interface. In practice, it is the dynamic characteristics as seen at the tip of the tool which determine the metal removal rate. It is more difficult to arrange for a change in drawbar force in a milling spindle, because the drawbar force is usually provided through a stack of springs, one purpose of which is to keep the drawbar force constant.

In our case we were able to measure the dynamic characteristics of a high speed spindle while the drawbar was being tested. The spindle was suspended from a hook using flexible nylon cords. FRF's were measured at the end of a 19 mm diameter 64 mm long solid carbide rod held in

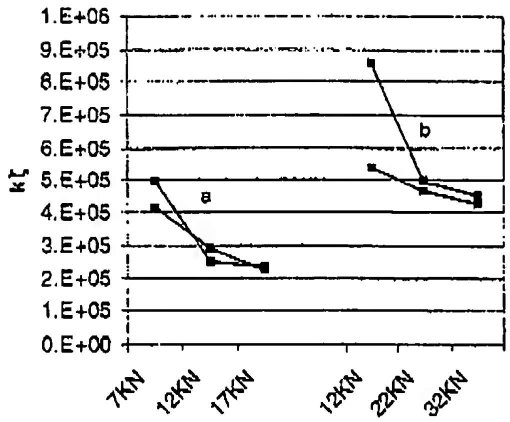

Figure 6: Product of damping ratio and modal stiffness for 2 different holders a) CAT-40 and b) CAT-50 versus drawbar force

an HSK-63-A shrink-fit holder. We measured FRF's at drawbar forces of 11.1 kN and 9.9 kN. Figures 7 and 8 show the Real and Imaginary Parts of the FRF for the 9.9 kN drawbar force. Here it can be seen that the imaginary peak value is -5.22×10^{-7} m/N, and the natural frequency of the most significant mode is 1000 Hz.

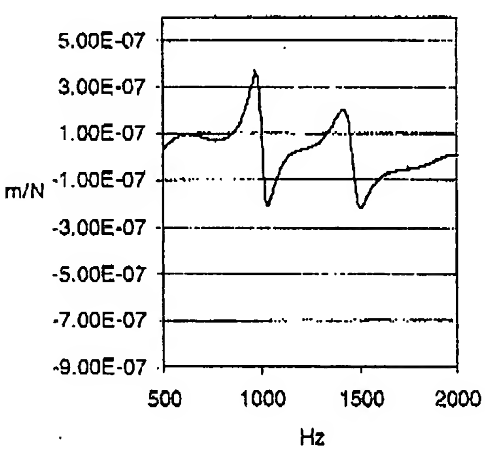

Figure 7: Real Part of a Frequency Response Function for a high speed spindle with an HSK-63-A connection and a 9.9 kN drawbar force.

Figures 9 and 10 show the corresponding measurement for the 11.1 kN drawbar force. In comparison to Figure 5, the natural frequency of the most significant mode has changed very little (to about 1012 Hz). The Imaginary Peak is -8.71×10^{-7} m/N.

In light of the test stand measurements, it seems likely that the difference in dynamic characteristics was caused by the difference in the drawbar force. The frequency remained

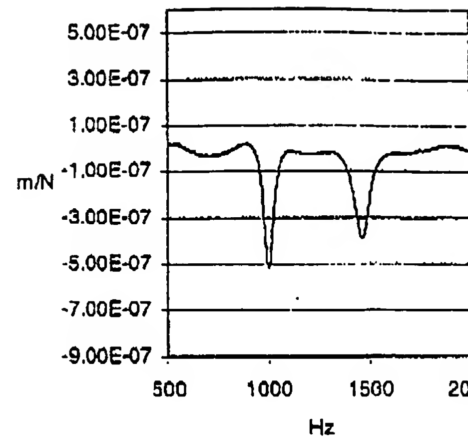

Figure 8: Imaginary Part of a Frequency Response Function for a high speed spindle with an HSK-63-A connection and a 9.9 kN drawbar force.

almost constant in the 2 cases, meaning that the modal mass and modal stiffness changed very little. The change in the height of the Imaginary Peak must be due mostly to a change in damping. Extraction of the model parameters from Figure 7, 8, 9, and 10 indicate that the lower drawbar force produced a damping ratio of about 0.035, while the higher drawbar force produced a damping ratio of about 0.021, a difference which accounts for almost all of the imaginary peak height change.

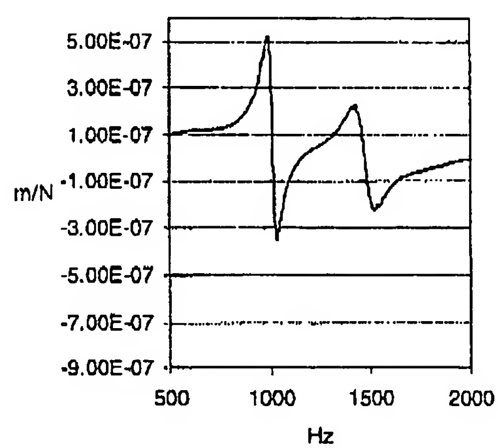

Figure 9: Real Part of a Frequency Response Function for a high speed spindle with an HSK-63-A connection and an 11.1 kN drawbar force.

From a stable metal removal rate perspective, the spindle with the lower drawbar force would have a better performance.

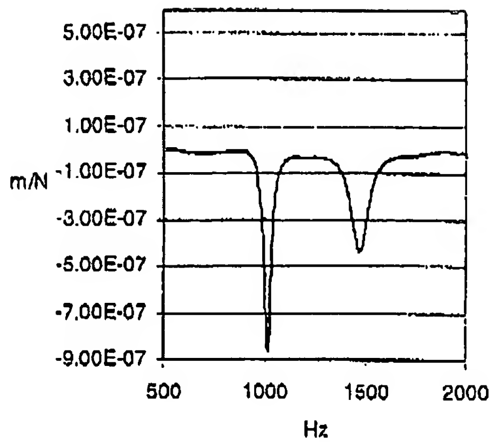

Figure 10: Imaginary Part of a Frequency Response Function for a high speed spindle with an HSK-63-A connection and a 11.1 kN drawbar force.

4 CONCLUSIONS

While an increase in drawbar force increases the static stiffness of toolholder - spindle interfaces, it also reduces the damping. Whether the higher drawbar force is beneficial for milling operations depends on whether the stiffness is increased more than the damping is decreased. We have observed several cases where the product of stiffness and damping is smaller for higher drawbar forces and larger for lower drawbar forces. We have observed this both in a specially-built test stand and in production spindles. We have observed this effect in both conventional CAT-type connections and in HSK-style connections.

These measurements indicate that at least in some drawbar force range, lower drawbar forces are preferable from a metal removal rate perspective. We believe that the damping comes from relative motion within the joint, and that this motion is inhibited by higher drawbar forces (that is, the connection behaves like an integral unit). Because lower drawbar forces may permit this relative motion, the effect of the drawbar force on the life of the connection is an interesting area for future investigation.

It may even be that different drawbar forces would be desirable, depending on the intended operation (somewhat less for high metal removal rate roughing operations, and somewhat higher for very accurate location operations). If this turns out to be the case, then a means of selecting the drawbar force on the shop floor or even from the NC program would be desirable.

In the short term, the meaning of these measurments is more clear. Because the drawbar force has such a strong influence on the dynamic stiffness, and therefore on the cutting performance, it is advisable to regularly monitor the drawbar force to correct any changes before they affect part quality.

5 ACKNOWLEDGEMENTS

We extend our sincere thanks to the National Center for Manufacturing Sciences (NCMS), and to John Agapiou of General Motors, for their assistance with equipment an d financial support. We are grateful to William Robert Winfough of Ingersoll Milling Machine and to the Boeing Company for their assistance in the development of this paper.

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